Quantifying the Impact of a Pigeon Dropping on the Output Power of a 10W PV Module

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***Abstract*—The output power from a stationary PV module tends to fluctuate throughout a day. This may be due to shading caused by clouds, contrails, trees, buildings and birds. The purpose of this paper is to quantify the impact of one pigeon dropping on the output power of a 10 W PV module that is located in a semi-arid region of South Africa. Data used in this experimental quantitative study was obtained from a LabVIEW software program that was designed to monitor and record the output power of a number of identical PV modules. Observations from this data enabled photographs to be taken of the PV modules that highlight the pigeon dropping. Results indicate that the instantaneous output power of these 10 W PV modules may be reduced by up to 5%, depending on the location of the single dropping. If the dropping is not removed, then a 1.5% power reduction can be realized for an entire day. A recommendation is to regularly clean these modules in areas that are well inhabited by pigeons, as every accumulated loss of power may lead to system downtime or even component failure over a period of time.**

***Index Terms*—Feral pigeons, Arduino, energy monitoring, excreta**

I. Introduction

"I hope I shall possess firmness and virtue enough to maintain what I consider the most enviable of all titles, the character of an honest man" [1]. These words, by a former American President George Washington, well highlight the importance that many people attach to maintaining an optimum moral character that is built around honesty. Similarly, when it comes to renewable energy systems that includes stationary photovoltaic (PV) modules, the goal should be to maintain the best, or optimum, possible output power throughout a given day.

However, various factors prove challenging in reaching this goal, that mainly focusses on the interruption of the direct-beam radiation from the sun. This interruption significantly lowers the output voltage of a PV module, thereby influencing the amount of output power available for driving a renewable energy system, which may lead to system downtime or even component failure over a period of time [2]. This interruption is usually due to shading of a PV module, either by natural or man-made causes.

Swart and Hertzog have reported on some of these natural causes that include feral pigeons [3] and cirrus clouds [2]. Man-made causes may be more evident to spot and may occur for longer periods of time. For example, 12 solar-tracking PV arrays, each consisting of 42 modules, where installed at one of the sports grounds of the Central University of Technology (CUT) in the Free State Province of South Africa (SA). One of the high-mast flood-lights at the ground casts a shadow over one of the arrays between 11 am and 1 pm (see Fig. 1). This man-made cause can be avoided by carefully planning the installation of a PV system. However, natural causes are not that easy to avoid, as they are largely random events. This is especially true of feral pigeons.

Fig. 1. Partial shading of a PV array at the Central University of Technology caused by a high-mast flood-light

Swart and Hertzog [3] found that pigeons spend, on average, 118 seconds at a time perched on top a PV module, where their tail and excreta cause the most significant impact in terms of interrupting the direct-beam radiation from the sun for an individual cell that forms part of a series string. Although these events are primarily random in nature, results do indicate that feral pigeon presence is lowest on a Wednesday during the week and in the summer periods between January and March of every year. Additional research has also reported that bird excreta, combined with humidity, can cause power line outages [4] and cause partial shading of a PV module [5].

The purpose of this paper is to quantify the impact of a single pigeon dropping on the output power of a 10 W PV module that is located in a semi-arid region of SA. An experimental quantitative study is used were the primary data is obtained from a LabVIEW software program that was designed to monitor and record the output power of a number of identical PV modules. This may have an impact on the design of an intervention that may be used to repel pigeons from a PV module. The structure of

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pigeon excreta is firstly reviewed, in order to understand its potential impact on the output power of a PV module. This is followed by a discussion of the research site and methodology. Results and conclusions end the paper.

II. Feral Pigeon Excreta

Feral pigeons (Columba Livia) are descended from rock doves (Columba Livia), a Eurasian species which roosts and nests on natural cliffs [6]. Feral pigeons are very active in the Free State province of SA that includes Bloemfontein, the provincial capital. In fact, one study showed that some 262 eggs were successfully hatched in just one year in a $4km^2$ area [7], while Bloemfontein has an average land size of $2367km^2$. The breeding activities of feral pigeons occur throughout the year in Bloemfontein, with a decrease between January and March when seasonal rainfall reaches a peak [7]. Since the diet of these feral pigeons consists almost exclusively of field crops, they regularly leave the city limits to feed [8]. More than other bird species, feral pigeons exhibit a behavior of short term resting, in the form of perching on elevated spots [9].

Feral pigeons have gained the reputation of being a major urban pest [10], as their excreta soils facades and causes health risks to humans and animals. A single pigeon can produce around 12kg of excreta every year [11], which can prove quite significant if the same flock of pigeons regularly return to the same nesting area. These birds are known to defecate before taking off as part of the fit-for-flight hypothesis [12].

Bird excreta are composed of three separate components mixed in the cloaca [13]. The first is the fecal (or stool) component. For most pet birds, this is the green to brown, solid part of the droppings. The color may vary with the type of food being fed, and is usually a creamy, whitish color for pigeons. The second component is the urate component, or the solid urine component. Unlike most animals, birds, in their attempt to conserve water, produce a solid urate component. The urates are usually white. The third component is a clear liquid urine component.

In real-life situations, pigeon excreta is deposited in many places, where the majority of damage would occur within the first two weeks of deposition [14]. After that, the majority of individual droppings would have either dissolved or desiccated to such a degree that they would disappear. A bird's urine and excreta (often termed guano when deposited in large amounts) are a primary source of soluble salts and uric acid.

Research confirms that pigeon droppings are a potential source of a wide range of salts, and should therefore be considered not only in terms of the substantial visual disamenity they cause, but also as a possibly important factor in long-term decay of stone that could result from salt crystallization [15]. Research further indicates that pigeon excreta has a moderately acidic pH level of around 6.5 with a high water content (75.7%–79.2 %, depending on feeding regimen) [16], which predicts shrinkage under naturally dry conditions. This water content enables the pigeon dropping to stick to the glass surface of a PV module after being freshly voided. A sticky pigeon dropping can often be seen as a sticky gooey mess, but eventually it dries out. However, a single dropping can remain attached to a PV module for a length of time. They are usually removed by rain and wind or by physically cleaning the module with a rubber squeegee and water.

Pigeon droppings are usually characteristically shaped (spiral on an edge) with an approximate diameter of 2cm [17]. The chemical properties and composition of pigeon feces (pH, uric acid, and nitrogen) create an excellent substrate for fungal spores to propagate [18], that includes Cryptococcus neoformans. This pathogen is frequently isolated from pigeon droppings and can cause meningitis in immunocompromised individuals [19]. It is known to infect a million people annually in Sub-Saharan Africa with two thirds of that number dying as a consequence. It is reported that up to 90% of HIV/AIDS patients contract opportunistic fungal infections due to a weakened immune system and that 10 to 20% die as a direct consequence of these infections [20]. This represents a very high number of immunocompromised people who are susceptible to infections or complications due to opportunistic pathogens that can reside in pigeon excreta.

III. Research Site

The research site is located roughly in the center of SA, in a city called Bloemfontein, that is well-known as a semi-arid region (see Fig. 2) [21].

This semi-arid region is characterized by water scarcity, hot dry weather, large areas of poor soils [22] and dust storms [23]. This region has a normal daily solar radiation of between 4500Wh and 7000Wh per square meter per day, making it ideal for renewable energy research relating to PV systems. It has an average annual precipitation of around 550mm, with more than half of this rainfall occurring between January and April. This further contributes to the idealness of the site, as minimum cloud cover occurs during the majority of the year. Indeed, the possible potential negative impact of pigeon excreta is evident for this study.

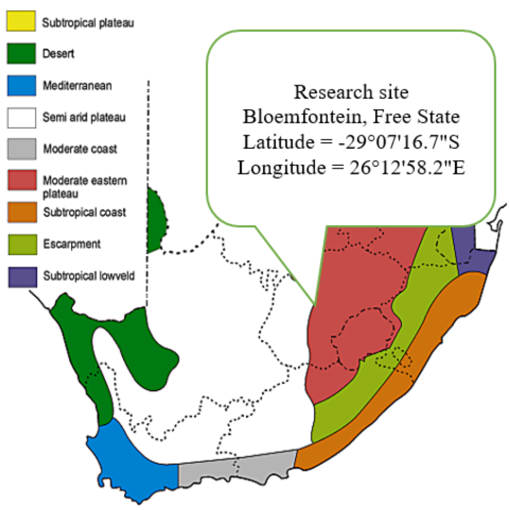

Fig. 2. Research site location in South Africa [21]

Localized dust storms often occur in late winter (August) due to open pan surfaces and large agricultural lands [24]. This provides a challenge, as the PV modules gather more dust than usual on their front glass surface. Midday temperatures in the summer season (December) may reach as high as 35℃. This also provides a challenge, as the output power of PV modules is reduced with higher ambient temperatures.

The Faculty of Engineering, Built Environment and Information Technology is located on the main campus of CUT, with a number of research facilities [25]. One such facility has a 4th floor balcony facing northwards, with unobstructed views of the sun. This guarantees no man-made interruption in the direct-beam radiation of the sun that is required by the stationary PV modules. However, natural interruptions in terms of feral pigeon presence on the PV module is realized.

IV. Methodology

The purpose of this paper is to quantify the impact of a single pigeon dropping on the output power of a 10W PV module that is located in a semi-arid region of SA. An experimental quantitative study is used. Data was obtained from a LabVIEW software program that was designed to monitor and record the output power of a number of identical PV modules.

Experimental designs are widely regarded as the most effective way to identify and gauge causality [26]. In this research, causality relates to the relationship between the presence of the feral pigeon dropping on the glass surface of a PV module and its subsequent output power.

This study draws on data collected during May 2018. Three identical 10 W PV modules were mounted on an aluminium frame with a tilt angle of 29° and an orientation angle of 0° north. This was done on the 4th floor balcony of the ETB Building on the main campus of CUT in Bloemfontein. A data logging interface circuit was used in conjunction with an Arduino Mega to sample and relay voltage and current values to a LabVIEW program. The program was designed to monitor and record instances where one of the three modules exhibited a dip in current while the other two modules remained constant. This was identified as an interruption in the direct-beam radiation that was mainly correlated to the presence of feral pigeons on the PV module. The process has been described by Swart and Hertzog [3]. This presence must firstly be determined, before the impact of any excreta can be evaluated. This was confirmed by physically taking a photo of the PV module. Images from the LabVIEW user interface and of the PV module are shown next in the results.

V. Results

The presence of a feral pigeon on a PV module is evident by a dip in the current curve as shown in Fig. 3.

This image represents the front panel of LabVIEW, where the following is evident:

- Point A – All three curves (PV1, PV2 and PV3) behave similarly until 09:34 am when PV1 (black line) drops significantly below 2W.
- Point B – The power drop is primarily due to the current drop (value less than 100mA), rather than a voltage drop, as the direct-beam radiation from the sun has been interrupted.
- Point C – PV2 and PV3 behave similarly in terms of output power. However, PV1 is consistently lower in output power. This is due to a dropping that has been left behind by the pigeon that originally perched on top of the PV module at 09:34 am.
- Point D – The pigeon dropping is removed from the PV module at 12:54 pm, resulting in its output power returning to normal, where it is similar to PV2 and PV3.

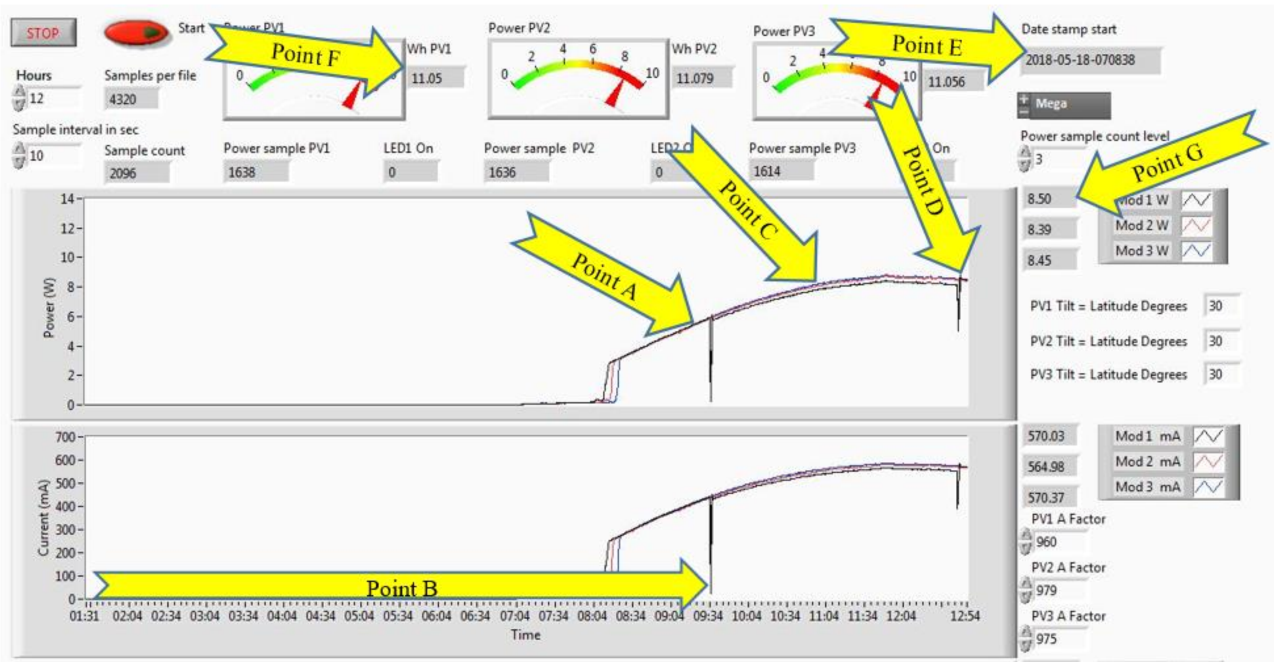

Fig. 3. Current curve dip indicating the presence of a pigeons on 18 May 2018

Fig. 4. Pigeon dropping visible on PV1 on 18 May 2018 at 12:39 pm.

- Point E – The time stamp indicates that this occurred on 18 May 2018, which is the same time stamp that is shown in Fig. 4 that represents a photo of the PV module where the pigeon dropping is visible on the top right hand side. Note the time in Fig. 4 is given as 12:39 pm, which is before 12:54 pm when the dropping is removed.
- Point F – The total output power of PV1 (as calculated from 06:34 am until 12:54 pm that equates to a sample count of 2096) is shown to be 11.05 W, which is similar to PV2 (11.079W) and to PV3 (11.056W). This illustrates that the power reduction needs to be calculated using the instantaneous output power and then correlated to the total output power obtained at the end of a day.
- Point G – The instantaneous output power of PV1 is shown to be 8.5W, which is similar to PV2 (8.39W) and PV3 (8.45W). This is due to the fact that the pigeon dropping has been removed and all three modules are now producing similar output powers.

Fig. 5 shows a zoomed view of Fig. 4, where the dropping is visible as covering the top portion of the third cell as counted from the right hand side. The cell size is 22mm by 78mm while the dropping is circular in nature with a mean diameter of 13mm. It is important to note that this is a 36 cell PV module, where the cells are connected in a series string. Subsequently, if one cell is partially shaded, it will impact on the entire series string, lowering the overall output current to that produced by the shaded cell [27]. It must also be noted that the position of the sun will cause the dropping to give various shading patterns during the day that will impact on the output power in varying levels. This is evident based on Fig. 6 and Fig. 7 that shows the glass surface of PV1 and the LabVIEW front panel for 14 May 2018.

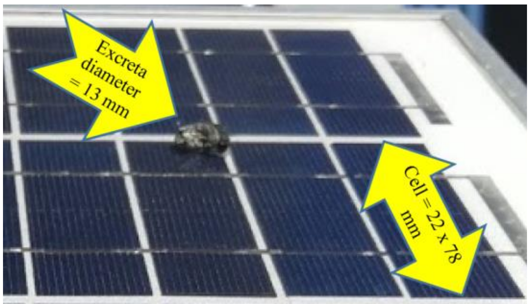

Fig. 5. Pigeon dropping visible on PV1 that shades a portion of a cell.

Fig. 6. Pigeon dropping visible on PV1 on 14 May 2018.

Fig. 7 suggests that no pigeon perched on the PV module, as no significant drop, or dip, in the current or power curve is observed. Please note that all three curves behave similarly between 11:04 am and 13:04 pm. However, prior to 11:04 am and after 13:04 pm (especially from Point 2 onwards), it is evident that the power curve of PV1 is below that of PV2 and PV3, suggesting some or other form of direct-beam interruption. A photo of the glass surface of this PV module reveals the reason for this in Fig. 6.

In Fig. 6, the excreta resides between two cells that causes no significant shading between 11:04 am and 13:04 pm as the sun is roughly perpendicular to the PV module. However, before 11:04 am, the sun is still rising in the sky that causes the excreta to cast a shadow on the cell to its right. In the afternoon, the sun is setting, causing the excreta to cast a shadow on the cell to its left. However, in this example, the instantaneous output power of the modules can be used to calculate the reduction in output power using the information captured in Fig. 7. PV1 shows an instantaneous output power of 4.75W (just right of point 2). This is 210mW lower than PV2 and 260mW lower than PV3. This gives rise to a reduction of 5.18 % for this time of the day. Obviously, this percentage is closer to 0 % at 12:00 pm, giving rise to the conclusion that the output power reduction percentage will vary throughout the day depending on the location of the dropping and the position of the sun.

Fig. 8 shows the LabVIEW front panel at 5 pm on 14 May 2018, taken 2 hours after Fig. 7. Point 3 in this figure highlights when the pigeon dropping was removed from the PV module, being 3 pm. The power curve of PV1 rejoins the curve of PV2 and PV3, where all three are again similar until 5 pm. Fig. 9 shows the difference in Watts between the 3 PV modules for the month of June 2018.

As discussed above, a pigeon dropping was found on the glass surface of PV1 on 14 and 18 May 2018. According to Fig. 9, PV2 and PV3 have a difference of only 300mW on 14 May, while an 800mW difference is observed between PV1 and PV2 and between PV1 and PV3. This equates to a power reduction of 1.5% for 14 May 2018 (PV1 generated 51.4 W while PV2 generated 52.2W for the day). A similar pattern is observed for 18 May 2018, but for a shorter period of time, as the pigeon dropping was removed from the PV module by using a rubber squeegee and water.

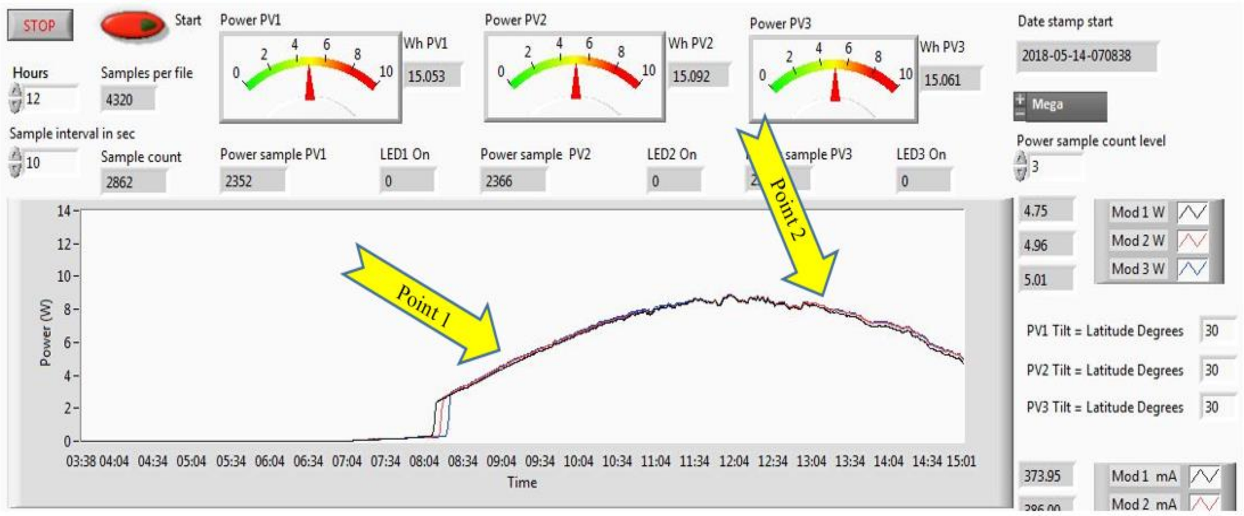

Fig. 7. LabVIEW front panel (user interface) showing three output power curves as at 3 pm on 14 May 2018

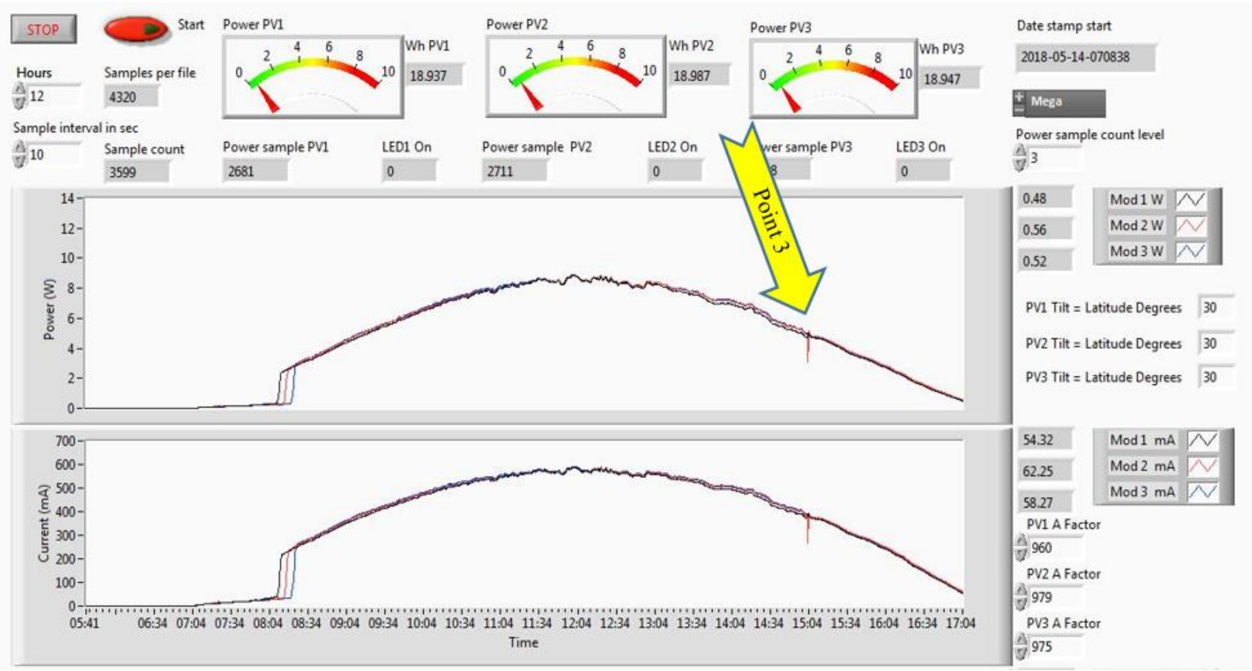

Fig. 8. LabVIEW front panel (user interface) showing three output power curves as at 5 pm on 14 May 2018

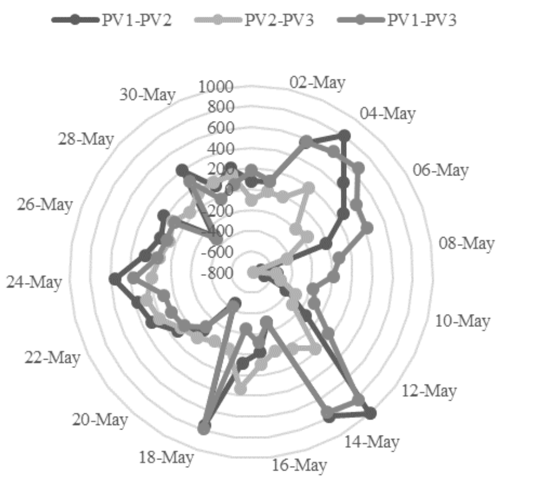

Fig. 9. Power difference in mW between the 3 PV modules for the month of May 2019

VI. Conclusions

The purpose of this paper was to quantify the impact of a single pigeon dropping on the output power of a 10W PV module that is located in a semi-arid region of SA. Pigeon droppings are usually spiral in form, with an average diameter of around 2cm. They have an average pH level of 6.5 with a high-water content around 78% that primarily enables the dropping to stick to the glass surface of a PV module. The length of time for this adhesion could also be determined in future studies.

Results indicate that the instantaneous output power of these 10 W PV modules may be reduced by up to 5%, depending on the location of a single dropping. If the dropping is not removed, then a 1.5% power reduction can be realized for an entire day. A recommendation is to regularly clean these modules in areas that are well inhabited by pigeons, as every accumulated loss of power may lead to system downtime or even component failure over a period of time.

Conflict of Interest

The author declares no conflict of interest.

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